Chirp Sonar Support for Mine Burial Program

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LONG TERM GOALS

The long term research objective is to develop a cost effective technique for mapping the top 20 meters of sediment properties using acoustic remote sensing. In previous years, a chirp sonar was developed to provide quantitative, wideband reflection measurements of the seabed with a vertical resolution of 10 cm. Neural network and fuzzy logic techniques have been used to automatically detect subsurface layer interfaces and to find the boundaries between sediment layers. Signal processing techniques were developed to estimate vertical profiles of impedance, attenuation and volume scattering coefficients. The procedures for remotely estimating sediment properties are being verified using core data and insitu measurements. New signal processing techniques have been developed that allow several sources transmitting simultaneously in different bands to build a wideband FM pulse in the far field. That wideband data is being used to improve the accuracy of the remote acoustic sediment property prediction procedures.

OBJECTIVES

1) Conduct chirp sonar surveys at Corpus Christi and Martha's Vineyard the proposed locations of the mine burial experiment sites to provide help select sites for mine burial experiments.

2) Calculate acoustic impedance, attenuation, phase velocity and dispersion from the chirp sonar data sets and provide the measurements to mine burial investigators needing sediment property data.

3) Compare acoustic property predictions to insitu acoustic and physical property measurements made by other investigators to establish accuracy of remote property predictions.

APPROACH

At the mine burial program sites in Corpus Christi and Martha's Vineyard, multiband chirp processing technology will be used to collect wideband FM data that has a flat spectrum over the range of 1.5 to 20 kHz. The resulting vertical resolution of reflection profiles is about a factor of 4 better than off the shelf chirp sonars without any degradation in subsurface penetration. The multiband technology allows the collection of normal incidence reflection data over at least one decade of frequencies while the towed vehicle emulates a point acoustic source. The point source is emulated using at least 2 piston sources that operate over contiguous and overlapping frequency bands. Each single piston source has a wide beamwidth (greater than 40 degrees) over its band of operation. Multiple transducers are driven simultaneously with chirp pulses with different bands to generate the wideband

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14. ABSTRACT
The long term research objective is to develop a cost effective technique for mapping the top 20 meters of sediment properties using acoustic remote sensing. In previous years, a chirp sonar was developed to provide quantitative, wideband reflection measurements of the seabed with a vertical resolution of 10 cm. Neural network and fuzzy logic techniques have been used to automatically detect subsurface layer interfaces and to find the boundaries between sediment layers. Signal processing techniques were developed to estimate vertical profiles of impedance, attenuation and volume scattering coefficients. The procedures for remotely estimating sediment properties are being verified using core data and insitu measurements. New signal processing techniques have been developed that allow several sources transmitting simultaneously in different bands to build a wideband FM pulse in the far field. That wideband data is being used to improve the accuracy of the remote acoustic sediment property prediction procedures.

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chirp pulse in the water that appears (in the far field) to emanate from a point acoustic source. Multiple rectangular receiving arrays of various sizes are used to control receiving beamwidth and scattering by their inherent spatial filtering.

A dual pulse mode of transmission has been developed to allow simultaneous collection of two data sets: a wideband shallow penetration data set using a low energy multi-octave FM pulse and a deep penetration data set for geologic imaging using a high energy, low frequency single-octave FM pulse. For example, a typical pair of alternating FM pulses could be a 10 msec 1.5 – 15 kHz FM pulse and a 40 msec 1.5-4 kHz FM pulse.

The sonar vehicle will be configured for measuring acoustic velocity. Three line arrays, oriented across track, are mounted under the sonar vehicle using an interarray spacing of 2 meters, thereby providing 3 receiver channel offsets from the projector. The difference in reflector arrival times will increase as the array offset and the angle of incidence increases. The seawater and sediment velocity can be calculated from the arrival time after corrections are made for vehicle attitude and seafloor slope. An integrated motion sensor measures the pitch and roll of the vehicle and its data is stored in the sonar data structure so vehicle attitude can be compensated for during processing. A pressure sensor that has an accuracy of 0.01% measures the submergence pressure of the vehicle and provides the data for vehicle motion compensation.

A supershort baseline sonar is used to measure the position of the sonar with respect to the surface ship. A DGPS antennae is mounted on the over the side SSBL transceiver pole to provide the absolute reference position. This positioning system provides approximately 10 meter accuracy in measuring sonar vehicle absolute position during the survey in up to 100 meters of water. Knowledge of absolute fish position is important for determining the towed sonar vehicle position relative to core sites used for ground truthing chirp sonar data.

The tow height above the seabed will be approximately 10 meters, a good height for minimizing scattering noise and nearfield interference. The normal incidence data measured by the four receiving channels(a large rectangular array for imaging and 3 line arrays for measuring velocity) will be matched filtered and stored with DGPS and vehicle motion data on removable harddrives in a SEGY – like format. Extensive pre-cruise and post-cruise calibration and testing procedures will be used to ensure the sonar has an absolute calibration over the entire frequency range.

The wideband chirp data is processed using several numerical techniques to obtain acoustic sediment properties. Initially a fuzzy logic based layer detection algorithm automatically locates and tracks sediment layer interfaces and stores sediment layer interface location, amplitude and phase data in memory. The phase is obtained by cross correlating the transmitted pulse with each interface echo to determine if the peak of the cross correlation function is positive or negative. A negative peak corresponds to an impedance decrease. Impedance profile is constructed from interface amplitude and phase data by iteratively calculating the impedance for each sediment layer starting at the sediment-water interface. The amplitude of each interface as a function of frequency is determined by bandpass filtering the data set into many frequency bands and measuring the amplitude of each interface reflection for each band. A ratio between amplitude vs frequency functions for two interfaces provides the attenuation function for sediments between the two interfaces. The slope of the attenuation function is the attenuation coefficient. Two hydrophone arrays, mounted across track in the tow vehicle, can be used to determined wate and sediment velocity given the array spacing of 2 meters and measurements of vehicle attitude and arrival times of reflections measured by the two line receiving channels. The phase dispersion can be measured by performing the velocity measurement in several

frequency bands to obtain phase speed as a function of frequency. The procedures provide vertical profiles of attenuation, impedance and velocity.

Dr. Schock supervises the research program including graduate and undergraduate students and at sea experiments. Jim Wulf is the lead electrical engineer who conducts sonar modifications and attends at sea experiments.

WORK COMPLETED

The first sonar survey is scheduled to commence on October 12, 2001 at the impact mine burial experiment site off Corpus Christi. In preparation for the experiment a SSBL was procured, interfaced to the chirp sonar and tested on the August 2001 Geoclutter cruise.

RESULTS

Subbottom imagery and predicted sediment property data will be available after conducting the Corpus Christi experiment in October 2001.

IMPACT/APPLICATIONS

Instrumentation and sediment classification procedures have been developed to predict the acoustic and physical properties of the seabed using normal incidence reflection data collected by FM subbottom profilers. This development provides a cost effective method of surveying the top 20 meters of the seabed and obtaining vertical profiles of attenuation, acoustic impedance, volume scattering. From these acoustic property profiles, vertical profiles of physical properties such as bulk density, grain size, and porosity can be estimated.

RELATED PROJECTS

"Remote Sediment Property Estimation From Chirp Data Collected During ASIAEX," ONR G&G Grant. The chirp sonar was used to generate imagery and remotely predict sediment properties in the East and South China Seas using the same techniques as described in this report.